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Application for Patent

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(באנגלית) **(English)**

METHOD AND APPARATUS FOR MEASURING TORQUE

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METHOD AND APPARATUS FOR MEASURING TORQUE

METHOD AND APPARATUS FOR MEASURING TORQUE

FIELD AND BACKGROUND OF THE INVENTION

The present invention relates to a method and apparatus for measuring torque, particularly the torque applied by a rotating drive shaft to a load via a driven shaft. The invention is especially useful in measuring the output torque of an automotive vehicle engine, and is therefore described below with respect to that application, but it will be appreciated that the invention is capable of being used in many other applications as well.

The instantaneous output torque of a vehicle engine can be used for controlling the fuel fed to the engine, and/or the ignition of the fuel, in order to increase the efficiency of the vehicle engine. It can also be used to provide an indication as to when an engine overhaul may be needed. Many torque measuring devices have been used for these purposes but efforts are continually being made to increase the precision of the torque measurement, to decrease the sensitivity of the torque measurement to rotational velocity or temperature variations and/or to provide a more simple and compact construction capable of convenient introduction into existing vehicles and of withstanding the harsh environmental conditions therein.

OBJECTS AND BRIEF SUMMARY OF THE PRESENT INVENTION

An object of the present invention is to provide a method, and also apparatus, having advantages in one or more of the above respects.

According to one broad aspect of the present invention, there is provided a method of measuring the torque applied by a drive shaft to a driven shaft along a common axis of rotation, comprising: coupling the shafts together by at least one torque sensor plate, by fixing the torque sensor plate to one of the shafts at a first fixation point eccentric with respect to the common axis of rotation, and to the other one of the shafts at a second fixation point spaced from the first fixation point; measuring the deformation of the torque sensor plate in a section thereof between the first and second fixation points; and utilizing the measured deformation to produce a measurement of the torque.

According to an important feature in the preferred embodiment of the invention described below, the second fixation point is spaced from the first fixation point along a tangential line substantially perpendicular to a radial line from the first fixation point to the axis of rotation, such that the deformed section of the torque sensor plate between the first and second fixation points is expanded or contracted, depending on the direction of rotation of the drive shaft.

According to a further important feature in the described preferred embodiment, the torque sensor plate is also fixed to the other one of the shafts at a third fixation point, the third fixation point being on the tangential line but on the opposite side of the first fixation point as the second fixation point, and being equally spaced from the first fixation point as the second fixation point, such as to produce, between the first and third fixation points, another section of the torque sensor plate which is deformed in the opposite sense as the first-mentioned section, during the rotation of the drive shaft, the latter deformation also being measured and utilized to produce a measurement of the torque.

In the preferred embodiment of the invention described below, the two shafts are coupled together by these torque sensor plates spaced 120° from each other with respect to the axis of rotation.

As will be described more particularly below, the method and apparatus having the foregoing features are capable of measuring torque with high precision and with relative insensitivity to rotational velocity and temperature variations. In addition, the method may be implemented in apparatus which is of a relatively simple and compact construction and which is capable of convenient introduction into existing vehicles and of withstanding the harsh environmental conditions therein.

Preferably, and as described more particularly below, the measurement of the deformation in the torque sensor plate is effected according to the technique described in U.S. Patent 6,621,278, of September 16, 2003, issued to the assignee of the present application, although it will be appreciated that other deformation measuring techniques could be used, such as by the use of conventional strain gauges.

Further features and advantages of the invention will be apparent from the description below.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention is herein described, by way of example only, with reference to the accompanying drawings, wherein:

Fig. 1 is an exploded three-dimensional view illustrating a torque measuring device constructed in accordance with the present invention, but showing only one of the torque sensor plates therein;

Fig. 2 is an end view diagrammatically illustrating the torque measuring device of Fig. 1 with the three torque sensor plates thereof;

Fig. 3 is an enlarged, fragmentary sectional view illustrating the one torque sensor plate of Fig. 1 and the manner it is coupled to the drive and driven shafts as shown in Fig. 1;

Fig. 4 is an enlarged view of the torque sensor plate of Figs. 1 and 3 and its connection to the electrical system for measuring the torque sensed by the torque sensor plate; and

Fig. 5 is a block diagram illustrating the electrical measuring system of Fig. 4.

It is to be understood that the foregoing drawings, and the description below, are provided primarily for purposes of facilitating understanding the conceptual aspects of the invention and various possible embodiments thereof, including what is presently considered to be a preferred embodiment. In the interest of clarity and brevity, no attempt is made to provide more details than necessary to enable one skilled in the art, using routine skill and design, to understand and practice the described invention. It is to be further understood that the embodiments described are for purposes of example only, and that the invention is capable of being embodied in other forms and applications than described herein.

DESCRIPTION OF A PREFERRED EMBODIMENT

The drawings illustrate the novel torque measuring method and apparatus of the present invention implemented in an automotive vehicle for producing a continuous measurement of the engine torque. In the illustrated implementation, the torque measurement is effected in the coupling between the flywheel connected to the engine output shaft, and the clutch disc connected to the engine gearbox shaft. This connection is

typically made by three fastening screws securing the flywheel to the clutch disc at their outer peripheries. Thus, the mechanical energy from the engine is transmitted via the flywheel and clutch disc by means of these three screws. Each screw is loaded with a total shearing force F=M/R, wherein "M" is the force applied to the screw, and "R" is the distance between the disc axis of rotation and the screw axis. The engine torque is the total force applied to the three screws, or 3F.

In the embodiment of the invention illustrated in the drawings, the loading of these screws is sensed in order to provide a measurement of the output torque of the engine.

Thus, Fig. 1 illustrates the coupling between the flywheel 2 connected via drive shaft 3 to the engine, and the clutch disc 4 connected via driven shaft 5 and the gearbox to the load. This coupling is effected by the three fastening screws mentioned above, one of which is shown at 6 passed through an opening 7 in the flywheel disc 2 and secured by locking ring 8 and nut 9 of the clutch disc 4. While Fig. 1 illustrates only one of the three fastening screws 6, Fig. 2 illustrates all three such screws, therein designated 6a, 6b and 6c, respectively, for coupling the flywheel disc 2 to the clutch disc 4.

In accordance with the present invention, a torque sensor plate, generally designated 10, is coupled by each of the three screws 6a, 6b, 6c (Fig. 2) between the flywheel disc 2 and to the clutch disc 4 in a manner to sense the torque transmitted via the three screws. While Fig. 1 illustrates only one such torque sensor plate 10 for screw 6, it will be appreciated that each of the three screws 6a, 6b and 6c shown in Fig. 2 is provided with such a torque sensor plate, as schematically shown at 10a, 10b and 10c in Fig. 2.

Torque sensor plate 10 is of a flat, elongated configuration best seen in Fig. 4. It is widest at its central section and decreases in width towards its two end sections. Its central section is formed with a central opening 11 for receiving fastening screw 6 which, as described above, secures the flywheel disc 2 to the clutch disc 4 by means of locking ring 8 and nut 9. Its two end sections are formed with openings 12, 13. Each of the latter openings receives another fastening screw 14, 15, which screws pass through aligned openings in the flywheel disc 2 and a nut (9) of the clutch disc 4. The latter screws receive locking rings 16, 17, and nuts 18, 19, to secure the opposite ends of the torques sensor plate 10 to the clutch disc 4.

It will thus be seen, as shown particularly in Fig. 3, fastener screw 6, passing through the center of the torque sensor plate 10, serves to fix the torque sensor plate to the clutch disc 4 at a first fixation point eccentric with respect to the common axis of rotation of the two discs constituted by shafts 3 and 5. It will also be seen that the other two fastener screws 14, 15, passing through the end openings 12, 13 of the torque sensor plate 10, serve to fix the torque sensor plate to the flywheel disc 2 at second and third fixation points, respectively, equally spaced on opposite sides of the first fixation point of fastener screw 6. Thus, the torque transmitted by flywheel disc 2 to the clutch disc 4 will subject torque sensor plate 10 to strains or deformations corresponding to the torque transmitted, as will be described more particularly below.

Fig. 2 illustrates the assembly of Fig. 1 when all three torque sensor plates are applied for coupling the flywheel disc 2 to the clutch disc 4 in the manner described above in Fig. 1 with respect to the single torque sensor plate 10 of Fig. 1. In Fig. 2, the three torque sensor plates, each corresponding to plate 10 in Fig. 1, are identified as 10a,

10b and 10c, respectively; and their three fastening screws, corresponding to screws 6, 14 and 15 in Fig. 1, are identified as 6a – 6c, 14a – 14c and 15a – 15c, respectively.

As shown particularly in Fig. 2, each of the three torque sensor plates 10a, 10b, 10c is mounted such that the first fixation point effected by the three screws 6a, 6b, 6c, is eccentric with respect to the common rotary axis RA of the two shafts 3, 5. In addition each of the second and third fixation points, effected by the screws 14a – 14c and 15a – 15c, respectively, is on a tangential line passing through the respective first fixation point of the respective screws 6a – 6c, i.e., on a line which is substantially perpendicular to a radial line from the respective first fixation point to the rotary axis RA of the two shafts. Thus, during the rotation of the shaft of the flywheel disc 2, a force will be applied by each of the three screws 6a – 6c to the three torque sensor plates 10a – 10c in the tangential direction, as shown by arrows A – C, respectively, in Fig. 2. Such a tangential force applied by each of the three screws 6a – 6c will produce a contraction of a section of the respective torque sensor plate 10a – 10c between the first fixation point (screws 6a – 6c) and the second fixation point (screws 14a – 14c), and an expansion of the section of the torque sensor plate on the opposite side, i.e., between the first fixation point (screws 6a – 6c) and the third fixation point (screws 15a – 15c).

The contracted and expanded sections of each torque sensor plate 10 are more particularly seen in Fig. 4. As shown in Fig. 4, each torque sensor plate 10 is formed with a slot formation, generally designated 20, to enhance the contraction and expansion of the sections of the torque sensor plate between the above-described three fixation points. Slot formation 20 includes a first pair of parallel slots 21, 22 between the central opening 11 and one end opening 12, and a second pair of parallel slots 23, 24 between the center

opening 11 and the other end opening 13. Slots 21, 22 thus define a first deformable section 25 between openings 11 and 12; and slots 23, 24 define a second deformable section 26 between openings 11 and 13. It will be seen that the two sections 25, 26 are deformed in opposite senses during the rotation of the two discs 2, 4, according to the force applied to their respective fastener screws 6; that is, when one of these sections is contracted, the other is elongated an equal amount, and vice versa.

Slot formation 20 formed in each torque sensor plate 10 includes two further pairs of parallel slots 31, 32 and 33, 34, respectively, located 90° with respect to slot pairs 21, 22 and 23, 24. A deformable section 35 is thus defined by slot pair 31, 32, and another deformable section 36 is defined by slot pair 33, 34. However, whereas sections 25 and 26 of the torque sensor plate are deformable by contraction or elongation, sections 35 and 36 are deformable by bending. The bending in sensor sections 35 and 36 thus enhances or concentrates the contraction or elongation in sensor sections 25, 26.

The contraction or elongation in sensor sections 25, 26 is further enhanced or concentrated by the additional slots shown in Fig. 4, namely the outwardly extending end slots 37 – 40 formed at the outer ends of the parallel slots 21 – 24, respectively, and the connecting slots 41 – 44 interconnecting the two pairs of slots 21 – 24 with the two pairs of slots 31 – 34.

It will thus be seen that the contraction or elongation of sections 25 and 26 of each torque sensor plate 10 will correspond to the force on the respective center fastener screw produced by the torque transmitted from the flywheel disc 2 to the clutch disc 4 via the respective torque sensor plate 10. The contraction or elongation of sensor sections 25, 26 may be measured by conventional strain gauges. Preferably, however, such

deformations are measured by the electrical measuring system described in the above-cited U.S. Patent 6,621,278, which permits extremely high accuracy to be achieved even with relative small deformations.

Such an electrical measuring system is schematically indicated by box 50 in Fig. 4, and is more particularly shown in Fig. 5. Broadly speaking, the deformation in each of the sections 25, 26 of the torque sensor plate 10 is measured by: transmitting a cyclically-repeating energy wave from one side of the respective section towards the other side; receiving the cyclically-repeating energy wave at the other side of the respective section; detecting a predetermined fiducial point in the received cyclically-repeating energy wave; continuously changing the frequency of transmission of the cyclically-repeating energy wave in accordance with the detected fiducial point of each received wave such that the number of waves received is a whole integer; measuring the change in frequency; and utilizing the measured change in frequency to produce a measurement of the deformation of the respective sensor section 25, 26.

Such a measurement would thus be of the force on the fastener screw 6 of the respective torque sensor plate produced by the engine torque. Thus, the total engine torque, i.e., the total torque transmitted between the flywheel disc 2 and the clutch disc 4, would be the summation of the torques transmitted by the three torque sensor plates 10a, 10b and 10c coupling the two discs together.

As shown in Fig. 4, each torque sensor plate 10 is provided with a first transmitter 51 at one side of its deformable section 25; a first receiver 52 at the opposite side of its deformable section 25; a second transmitter 53 at one side of its deformable section 26; and a second receive 54 at the opposite side of its deformable section 26. In

the described preferred embodiment, the two transmitters and receivers are both of the acoustical type for transmitting and receiving cyclically-repeating acoustical waves.

The electrical measuring system shown within block 50 in Fig. 4, for measuring the elongation and contraction of the sensor sections 25 and 26 of the torque sensor plates 10a – 10c, is more particularly illustrated in Fig. 5. For the sake of simplicity, Fig. 5 illustrates only the circuitry of the electrical system operative with transmitter 51 and receiver 52 for measuring the elongation or contraction of sensor section 25 of one of the torque sensor plates 10a – 10c. It will be appreciated, however, that the system would also include the circuitry operative with transmitter 53 and receiver 54 for sensing the elongation or contraction of sensor section 26 of the respective torque sensor plate, as well as the circuitry for sensing the contraction and expansion occurring in the remaining two torque sensor plates during the transmission of the torque from flywheel disc 2 to clutch disc 4.

Thus, as shown in Fig. 5, the electrical measuring system 50 includes an oscillator 55 for initially driving transmitter 51 via a switch SW until an acoustical wave from the transmitter is received by the receiver 52. Once such a wave is received by receiver 52, switch SW is opened, so that the signals received by receiver 52 are thereafter used for controlling the frequency of transmission of transmitter 51.

As shown in Fig. 5, the signals received by receiver 52 are fed to a comparator 56 via its input 56a. Comparator 56 includes a second input 56b connected to a predetermined bias so as to detect a predetermined fiducial or reference point in the received signal. In the example illustrated in Fig. 5, this predetermine fiducial point is the "0" cross-over point of the received signal, and therefore input 56b is at a zero-bias.

Other reference points could be used as the fiducial point, such as the maximum or minimum peak of the received signals.

The output of comparator 56 is fed to an amplifier 57 which is triggered to produce an output wave or signal for each fiducial point ("0" cross-over point) in the signals received by the receiver 53. The signals from amplifier 57 are fed via an OR-gate 58 to the transmitter 52. OR-gate 58 also receives the output from oscillator 55 when switch SW is closed.

Switch SW is opened when transmitter 52 receives a continuous stream of signals from amplifier 57 via OR-gate 58. When switch SW is opened, transmitter 52 will thus transmit at a frequency determined by the fiducial point in the signals received by the receiver 53 and detected by comparator 56 to control amplifier 57. Accordingly, the frequency of transmission by transmitter 52 will be such that the number of waves of the cyclically-repeating energy wave transmitted from transmitter 51 and received by receiver 52 will be a whole integer.

It will thus be seen that while the frequency of the transmitter 52 will change with a change in the distance between it and the receiver 53, as caused by the elongation or contraction of sensor section 25, the number of wavelengths in the signal transmitted from transmitter 52 will remain a whole integer. This is because, as explained above, the transmitter 52 transmissions are controlled by the fiducial points ("0" cross-over point) of the signals received by the receiver 53. This change in frequency by the transmitter 52, while maintaining the number of waves between the transmitter and receiver as a whole integer, enables a precise determination to be made of the distance between the transmitter and receiver. Thus, as known:

$$F=C/\lambda$$

where F and C are the frequency and velocity, respectively, of the cyclically-repeating energy wave in the respective medium; and λ is the wavelength.

The "0" cross-over points detected in comparator 56, which are used for controlling the frequency of the transmitter 52, are also fed to a counter 60 to be counted "N" times, and the output is fed to another counter 61 controlled by a clock 62. Counter 61 produces an output to a microprocessor 63 which performs the computations of the engine torque according to the elongations and contractions measured, and a display 64 which displays the output of the microprocessor.

The output of microprocessor 63 thus represents the measured torque. It may be applied as a control signal, as shown at 65, to control the feed of the fuel to the engine or the ignition of the fuel. It may also be used to provide a continuous indication of the engine torque output, whether an overhaul condition may be necessary, or any other information or control relevant to the engine torque output.

Further particulars as to the measuring system illustrated in Fig. 5 are available in the above-cited U.S. Patent 6,621,278, the contents of which are incorporated herein by reference. It has been found that using such a measuring system for measuring the above-described deformations in the torque sensor plate produces a torque measurement of extremely high precision. While such a measuring system is therefore preferred, other electrical measuring systems for measuring the deformations in the torque sensor plates may be used, such as conventional strain gauges.

It has also been found that using a torque sensor, which undergoes an elongation in one section and a complementary contraction in another section, produces not only a

highly-precise measurement of torque, but also a measurement which is relatively insensitive to temperature or angular velocity variations. Thus, the influence of temperature is the same in both the expansion signal and the contraction signal, and therefore subtracting one signal from the other eliminates the temperature influence. In addition, since in the described preferred embodiment, the force which is sensed is a tangential force with respect to the rotary axis, rather than a radial force, the output signals produced are relatively unaffected by the rotational velocity, which produces radial (centrifugal) forces.

Further advantages of the described preferred embodiment are that it provides a simple and compact construction which is conveniently incorporatable in existing vehicle transmission systems and which is capable of withstanding harsh environments.

The torque sensor plates is preferably metal in the vehicle embodiment described, producing relative small elongations and contractions, but in other embodiments, they may be of plastic or rubber having good ultrasound conductivity, producing larger elongations and contractions. The elongations and contractions of each of the sensor plates 10a – 10c may be measured as described above to produce a precise measurement of the total torque, or only those on one sensor plate may be actually measured and the torque represented by such measurements may be multiplied by three to obtain a close approximation of the total torque. The outputs of the sensors may be fed to the electrical measuring system via slip rings, wireless transmitters, etc.

Therefore, while the invention has been described with respect to one preferred embodiment, it will be appreciated that this is set forth merely for purposes of example, and that many other variations, modifications and applications of the invention may be made.

WHAT IS CLAIMED IS:

1. A method of measuring the torque applied by a drive shaft to a driven shaft along a common axis of rotation, comprising:

coupling said shafts together by at least one torque sensor plate, by fixing the torque sensor plate to one of said shafts at a first fixation point eccentric with respect to said common axis of rotation, and to the other one of said shafts at a second fixation point spaced from said first fixation point;

measuring the deformation of said torque sensor plate in a section thereof between said first and second fixation points;

and utilizing said measured deformation to produce a measurement of said torque.

2. The method according to Claim 1, wherein said second fixation point is spaced from said first fixation point along a tangential line substantially perpendicular to a radial line from said first fixation point to said axis of rotation, such that the deformed section of the torque sensor plate between said first and second fixation points is expanded or contracted, depending on the direction of rotation of said drive shaft.

3. The method according to Claim 2, wherein said torque sensor plate is also fixed to said other one of said shafts at a third fixation point, said third fixation point being on said tangential line but on the opposite side of said first fixation point as said second fixation point, and being equally spaced from said first fixation point as said second fixation point, such as to produce, between said first and third fixation points, another section of the torque sensor plate which is deformed in the opposite sense as said

first-mentioned section during the rotation of said drive shaft; said latter deformation also being measured and utilized to produce a measurement of said torque.

4. The method according to Claim 3, wherein said torque sensor plate is formed with a slot formation including two pairs of parallel slots, each pair defining one of said sections of the torque sensor plate undergoing an expansion or contraction deformation during the rotation of the drive shaft.

5. The method according to Claim 4, wherein said slot formation includes further slots joined to said two pairs of slots and effective to enhance the expansion or contraction deformation of said sections of the torque sensor plate defined by said two pairs of slots.

6. The method according to Claim 1, wherein the two shafts are coupled together by a plurality of said torque sensor plates equally spaced eccentrically around the axis of rotation of the shafts.

7. The method according to Claim 6, wherein there are three of said torque sensor plates spaced 120° from each other with respect to said axis of rotation.

8. The method according to Claim 1, wherein said torque sensor plate is of metal.

9. The method according to Claim 1, wherein said torque sensor plate is of plastic or rubber.

10. The method according to Claim 1, wherein the deformation of said torque sensor plate in the section between said first and second fixation points is measured by:

transmitting a cyclically-repeating energy wave from one side of said section towards the other side of said section;

receiving the cyclically-repeating energy wave at the other side of said section;

detecting a predetermined fiducial point in the received cyclically-repeating energy wave;

continuously changing the frequency of transmission of the cyclically-repeating energy wave in accordance with the detected fiducial point of each received wave such that the number of waves received is a whole integer;

measuring the change in frequency; and

utilizing the measured change in frequency to produce a measurement of the deformation of the torque sensor plate in said section between said first and second fixation point, and thereby a measurement of said torque.

11. The method according to Claim 10, wherein said cyclically-repeating energy wave is an acoustical wave.

12. The method according to Claim 1, wherein said drive shaft is the output shaft of a vehicle engine.

13. Apparatus for measuring the torque applied by a drive shaft to a driven shaft along a common axis of rotation, comprising:

at least one torque sensor plate fixed to one of said shafts at a first fixation point eccentric with respect to said common axis of rotation, and to the other one of said shafts at a second fixation point spaced from said first fixation point;

and an electrical system for measuring the deformation of said torque sensor plate in the section thereof between said first and second fixation points, and for utilizing said measured deformation to produce a measurement of said torque.

14. The apparatus according to Claim 13, wherein said second fixation point is spaced from said first fixation point along a tangential line substantially perpendicular to a radial line from said first fixation point to said axis of rotation, such that the deformed section of the torque sensor plate between said first and second fixation points is expanded or contracted, depending on the direction of rotation of said drive shaft.

15. The apparatus according to Claim 14, wherein said torque sensor plate is also fixed to said other one of said shafts at a third fixation point, said third fixation point being on said tangential line but on the opposite side of said first fixation point as said second fixation point, and being equally spaced from said first fixation point as said second fixation point, such as to produce, between said first and third fixation points, another section of the torque sensor plate which is deformed in the opposite sense as said first-mentioned section during the rotation of said drive shaft; said latter deformation also being measured and utilized to produce a measurement of said torque.

16. The apparatus according to Claim 15, wherein said torque sensor plate is formed with a slot formation including two pairs of parallel slots, each pair defining one of said sections of the torque sensor plate undergoing an expansion or contraction deformation during the rotation of the drive shaft.

17. The apparatus according to Claim 16, wherein said slot formation includes further slots joined to said two pairs of slots and effective to enhance the expansion or contraction deformation of said sections of the torque sensor plate defined by said two pairs of slots.

18. The apparatus according to Claim 13, wherein the two shafts are coupled together by a plurality of said torque sensor plates equally spaced eccentrically around the axis of rotation of the shafts.

19. The apparatus according to Claim 18, wherein there are three of said torque sensor plates spaced 120° from each other with respect to said axis of rotation.

20. The apparatus according to Claim 13, wherein said torque sensor plate is of metal.

21. The apparatus according to Claim 13, wherein said torque sensor plate is of plastic or rubber.

22. The apparatus according to Claim 13, wherein said electrical system measures the deformation of said torque sensor plate in the section between said first and second fixation points by:

transmitting a cyclically-repeating energy wave from one side of said section towards the other side of said section;

receiving the cyclically-repeating energy wave at the other side of said section;

detecting a predetermined fiducial point in the received cyclically-repeating energy wave;

continuously changing the frequency of transmission of the cyclically-repeating energy wave in accordance with the detected fiducial point of each received wave such that the number of waves received is a whole integer;

measuring the change in frequency; and

utilizing the measured change in frequency to produce a measurement of the deformation of the torque sensor plate in said section between said first and second fixation point, and thereby a measurement of said torque.

23. The apparatus according to Claim 22, wherein said cyclically-repeating energy wave is an acoustical wave.

24. The apparatus according to Claim 13, wherein said drive shaft whose torque is measured is the output shaft of a vehicle engine.

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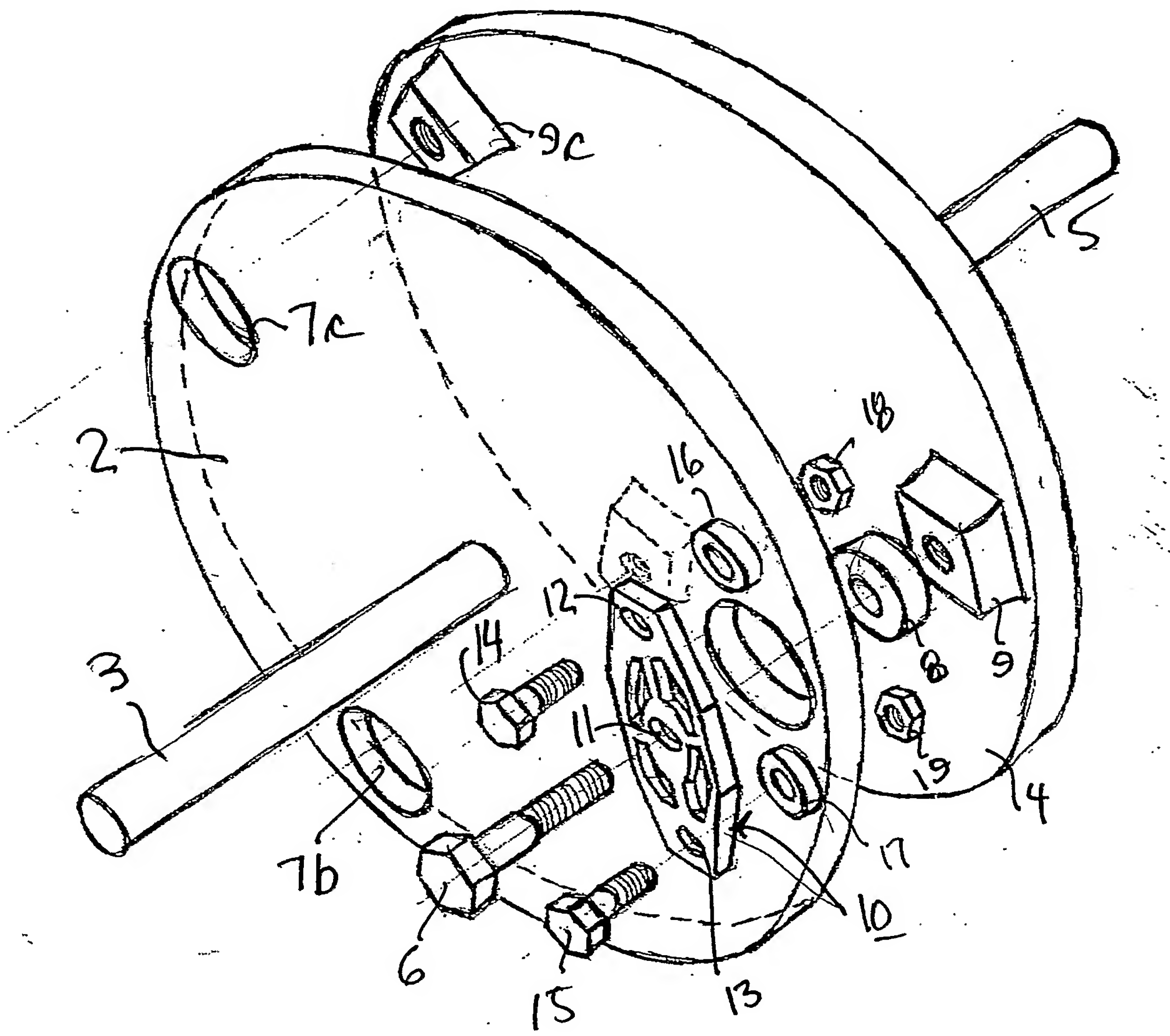


Fig. 1

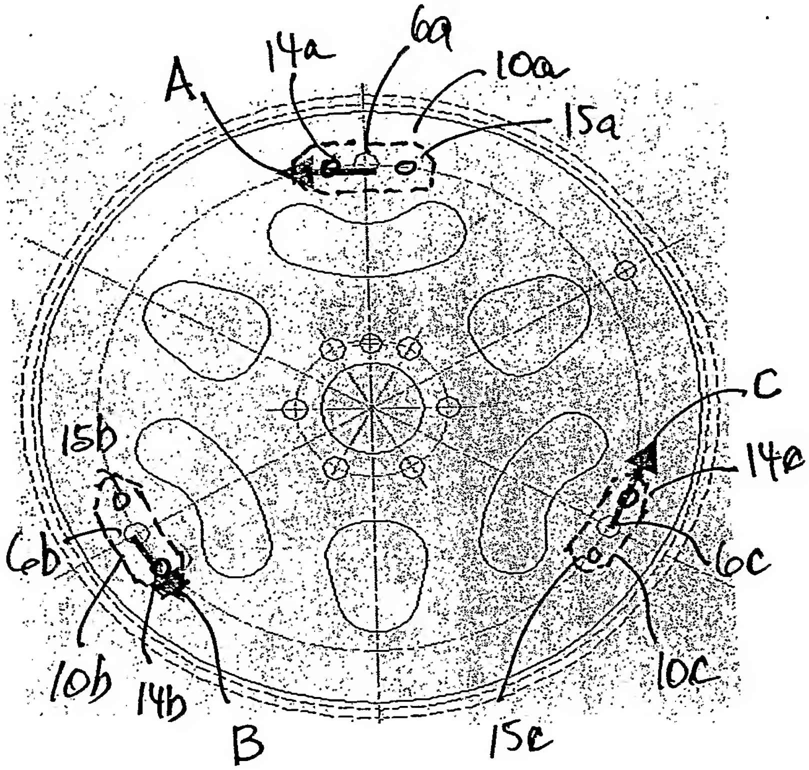

A
14a
6a
10a
15a
C
14c
15b
6b
6c
10b
14b
B
15c
10c

Fig.2

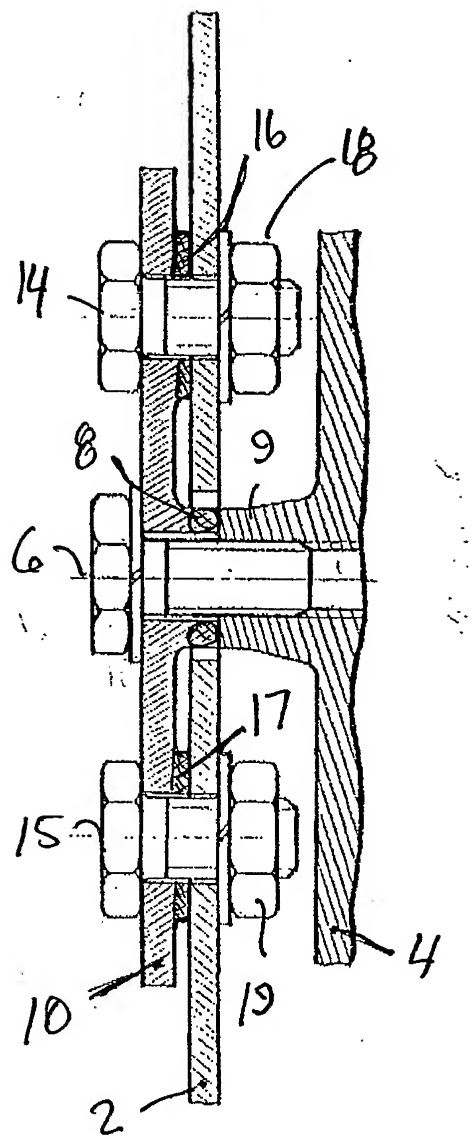
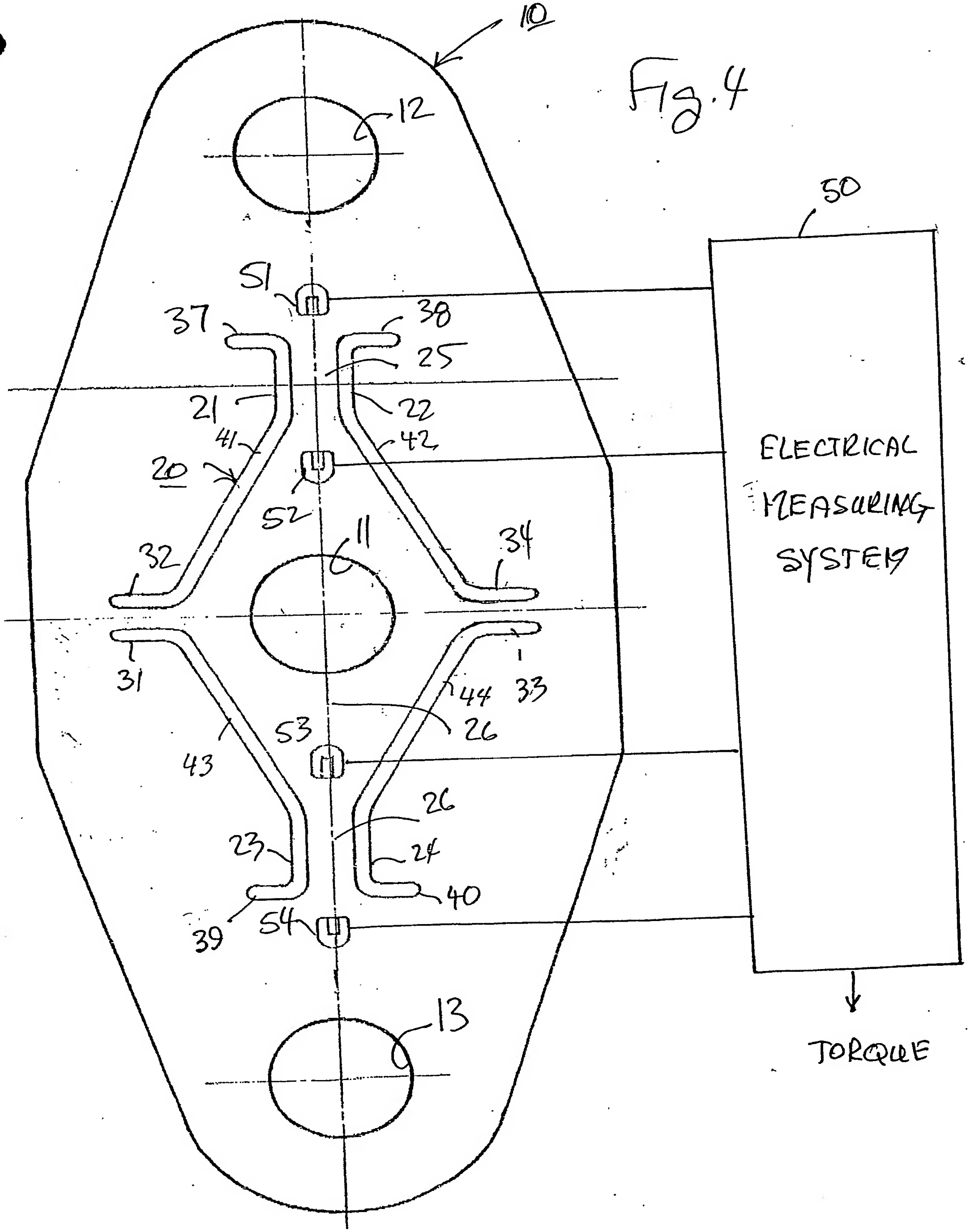

16
18
14
8
9
6
17
15
4
10
19
2

Fig.3


10
Fig.4
12
50
51
37
38
25
21
22
41
42
20
52
11
32
34
ELECTRICAL
MEASURING
SYSTEM
31
44
33
53
26
43
26
23
24
40
39
54
13
TORQUE

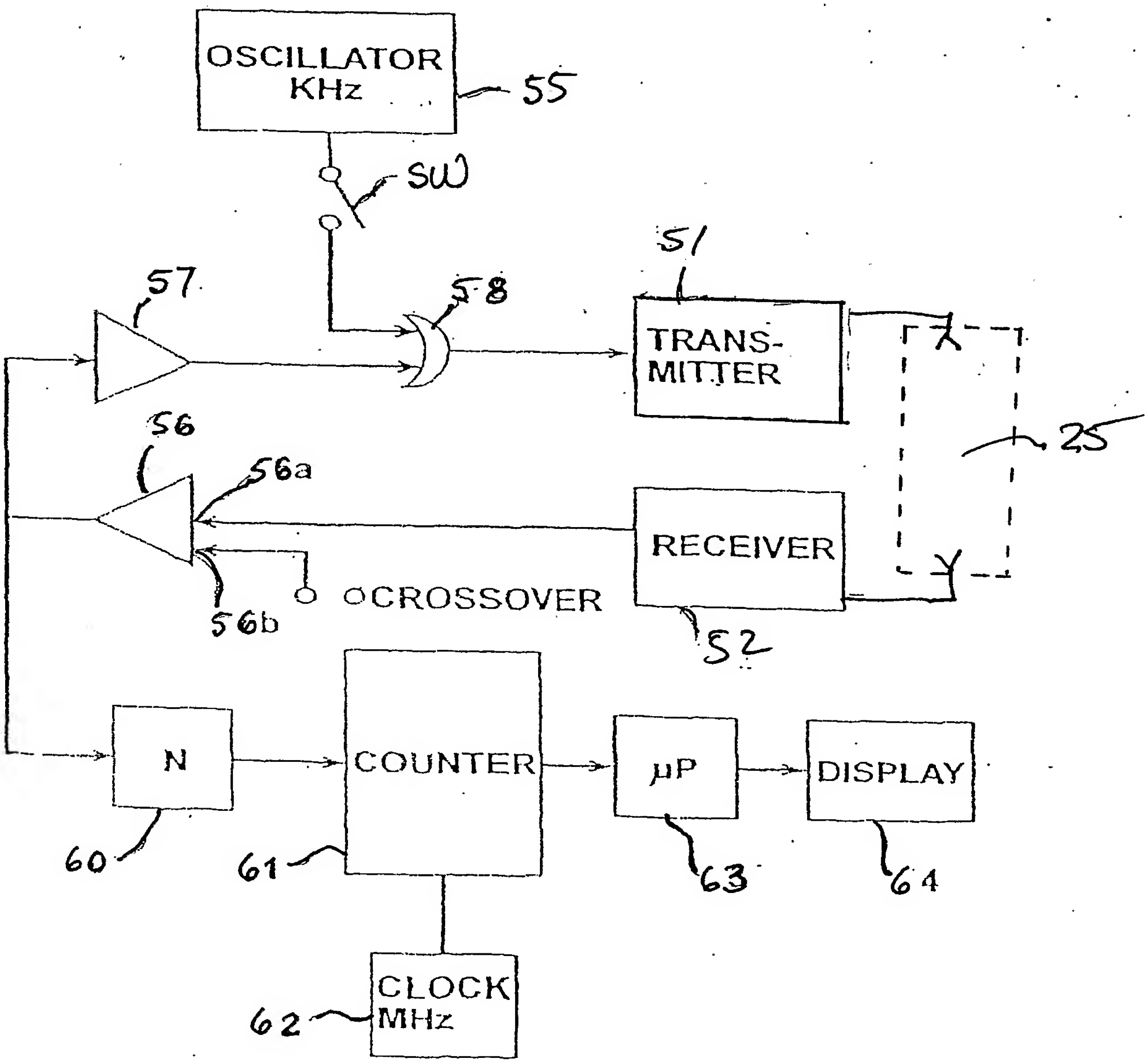

OSCILLATOR KHz
55
SW
51
57
58
TRANS-MITTER
25
56
56a
RECEIVER
56b
CROSSOVER
52
N
COUNTER
µP
DISPLAY
60
61
63
64
CLOCK MHz
62

Fig.5